



**UNIVERSITI PUTRA MALAYSIA**

**EXPERIMENTAL STUDY OF SHEET EROSION  
ON SLOPES**

**BOBBY SOON**

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**EXPERIMENTAL STUDY OF SHEET EROSION  
ON SLOPES**

**By**

**BOBBY SOON**

**Thesis Submitted to the School of Graduate Studies, Universiti Putra  
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Science**

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in  
fulfilment of the requirements for the degree of Master of Science

**EXPERIMENTAL STUDY OF SHEET EROSION  
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**August 2002**

**Chairman : En. Shukri Maail**

**Faculty : Engineering**

There is a need to determine a suitable Total Soil Loss Equation for the types of soil in and around the various Malaysian landscape. Currently there exists many methods, such as the linear equations and Revised Universal Soil Loss Equation (RULSE) that attempt to estimate the Soil Loss of a particular type of soil for different slope lengths, types of cover, rain intensity, slope gradient and kinetic energy of rain droplets.

The objective of this study was to propose a method of estimating the Total Soil Loss for two particular types of soil at different ranges of slope gradient by observing the sheet erosion of the slope surface and utilising experimental method. The method employed are by simulating sheet erosion using artificial rainfall on sample plot in a controlled laboratory environment and attempting to observed trend of the results collected and correlate the results for different slope gradients. It was the aim of this project to establish a terminal gradient whereby soil erosions is kept to a minimum for

the Malaysia landscape by controlling the gradient of the land. The correlation will be focused on the linear and polynomial type equations recommended by other researchers.

From the results of this study, it can be concluded that the derived equation accurately predicted the Total Soil Loss for the particular type of soil used and rainfall intensity. This is shown by the accuracy values of the regression analysis trend line plotted. The proposed Total Soil Loss Equation provides a convenient and fast method of assessing the predicted Total Soil Loss for two particular local soil types for various slopes. Although there exists various other methods of assessing and predicting the Total Soil Loss for different types of slope gradient, they are often based on unsuitable non-local conditions, are very tedious for simple predictions and requires large number variables and historical data. The Empirical Formulas derived are,

**i) For Sandy Soil**

**Equation (4.3a):**

$$\text{Total Soil Loss (metric tonnes/hectares)} = 4.525 \times 10^{-4} + (1.347 \times 10^{-5}) S + (1.194 \times 10^{-5}) S^2$$

$$(\text{Accuracy, } R^2 = 0.9)$$

**ii) For Clayey Soil**

**Equation (4.6a):**

$$\text{Total Soil Loss (metric tonnes/hectares)} = 1.37 \times 10^{-3} + (2.046 \times 10^{-5}) S + (1.137 \times 10^{-6}) S^2$$

$$(\text{Accuracy, } R^2 = 0.9)$$

$$S = \text{Slope (\%)}$$

Abstrak tesis dikemukakan kepada Senat Universiti Putra Malaysia  
Sebagai memenuhi keperluan untuk ijazah Master Sains

**KAJIAN PENILAIAN HAKISAN LAPIS  
DI PERMUKAAN CERUN**

Oleh

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**Ogos 2002**

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Terdapat keperluan dalam menentukan satu persamaan bagi Jumlah Hakisan Tanah yang sesuai untuk jenis tanah yang berlainan di pelbagai lanskap di Malaysia. Pada masa ini, terdapat beberapa persamaan untuk menentukan Jumlah Hakisan Tanah yang menggunakan persamaan lurus dan Persamaan (Semakan) Umum Kehilangan Jumlah Hakisan Tanah (RUSLE) yang digunakan untuk menentukan jumlah hakisan bagi jenis tanah berlainan menggunakan factor seperti jenis tanah, panjang cerun, tanaman penutup bumi, keadaan hujan, kecerunan permukaan dan tenaga kinetik titisan air hujan.

Objektif projek ini adalah untuk menentukan satu cara untuk menganggar kehilangan Jumlah Hakisan Tanah untuk dua jenis tanah berlainan pada kecerunan permukaan berbeza dengan menggunakan cara ujikaji dan pemerhatian hakisan permukaan di makmal. Cara yang digunakan adalah dengan menggalakkan hakisan permukaan menggunakan hujan tiruan pada petak sampel tanah di dalam keadaan terkawal di makmal dan membuat perhatian untuk keputusan yang didapati. Tujuan

projek ini juga adalah untuk menentukan had kecerunan dimana kecenderungan hakisan permukaan adalah minimum sebagai panduan untuk mengawal kecerunan di kawasan pertanian.

Kajian ini mendapati bahawa persamaan untuk menentukan Jumlah Kehilangan Hakisan Tanah yang dicadangkan adalah tepat untuk jenis tanah, keadaan hujan dan keadaan tanah yang digunakan. Ketepatan ini ditunjukkan oleh ketepatan analisis graf yang diplot. Persamaan Jumlah Hakisan Tanah ini juga memberi satu cara yang mudah dan cepat untuk menentukan jumlah hakisan tanah untuk dua jenis tanah tempatan pada kecerunan berlainan. Perlu juga dinyatakan bahawa walaupun terdapat persamaan lain untuk menentukan jumlah hakisan tanah. Namun persamaan lain kebanyakannya adalah bukan berdasarkan keadaan tempatan, adalah sangat rumit untuk membuat ramalan ringkas dan memerlukan banyak faktor berlainan dan data sejarah yang panjang. Persamaan yang ditentukan adalah,

**i) Untuk Tanah Berpasir**

$$\begin{aligned}\text{Jumlah Kehilangan Tanah (tan metrik/hektar)} &= 4.525 \times 10^{-4} + (1.347 \times 10^{-5}) S + \\ &(1.194 \times 10^{-5}) S^2 \\ &(\text{Ketepatan , } R^2 = 0.99)\end{aligned}$$

**ii) Untuk Tanah Berlumpur**

$$\begin{aligned}\text{Jumlah Kehilangan Tanah (tan metrik/hektar)} &= 1.37 \times 10^{-3} + (2.046 \times 10^{-5}) S + \\ &(1.137 \times 10^{-6}) S^2 \\ &(\text{Ketepatan , } R^2 = 0.99) \\ S &= \text{Kecerunan (\%)}\end{aligned}$$

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I certify that an Examination Committee met on 30<sup>th</sup> August 2002 to conduct the final examination of Bobby Soon on his Master of Science thesis entitled "Experimental Study of Sheet Erosion on Slopes" in accordance with the Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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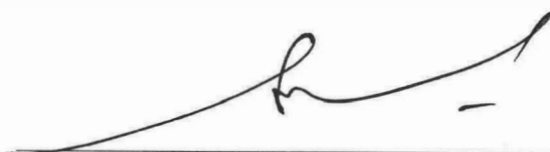
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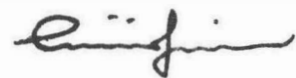
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## DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been acknowledge. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.



BOBBY SOON

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## CHAPTER 1

### INTRODUCTION

#### 1.0 Introduction and objective

Vast areas of virgin forest that covers the Peninsular Malaysia are being cleared rapidly to cope with the demand of land for agriculture and other developments. (Soong et. al, 1980). The effects of such extensive land clearing in are beginning to be felt in all sectors.

Soil losses and sedimentation of rivers, lakes and reservoir are direct effect of the clearing of trees that holds soil and protect it from erosion. The natural outcome from such situation are the flooding, choking up of waterways, sedimentation of reservoir and the loss of good topsoil suitable for agriculture. Soong et. Al (1980) have documented the soil losses in three catchment areas in Cameron Highlands, in the state of Pahang, Malaysia as shown below in Figure 1.1;

- i) in jungle area =  $24.5 \text{ m}^3 / \text{km}^2 / \text{year}$
- ii) in the tea plantation area =  $488 \text{ m}^3 / \text{km}^2 / \text{year}$
- iii) in the vegetable farm area =  $732 \text{ m}^3 / \text{km}^2 / \text{year}$

This effect increases as the areas in question are in a hilly and the soil surface are at gradient.

Beside deforestation other activities that contributes to the soil loss and sedimentation are mining, logging, agriculture and logging. The sediment from these activities naturally find their ways to the waterways and choking them. The results are polluted water which is not suitable for drinking and causes reservoir sedimentation, reduction of storage, and damage to generator blades.

The direct results from the water carrying high sedimentation load is the damage of natural environment and national economy.

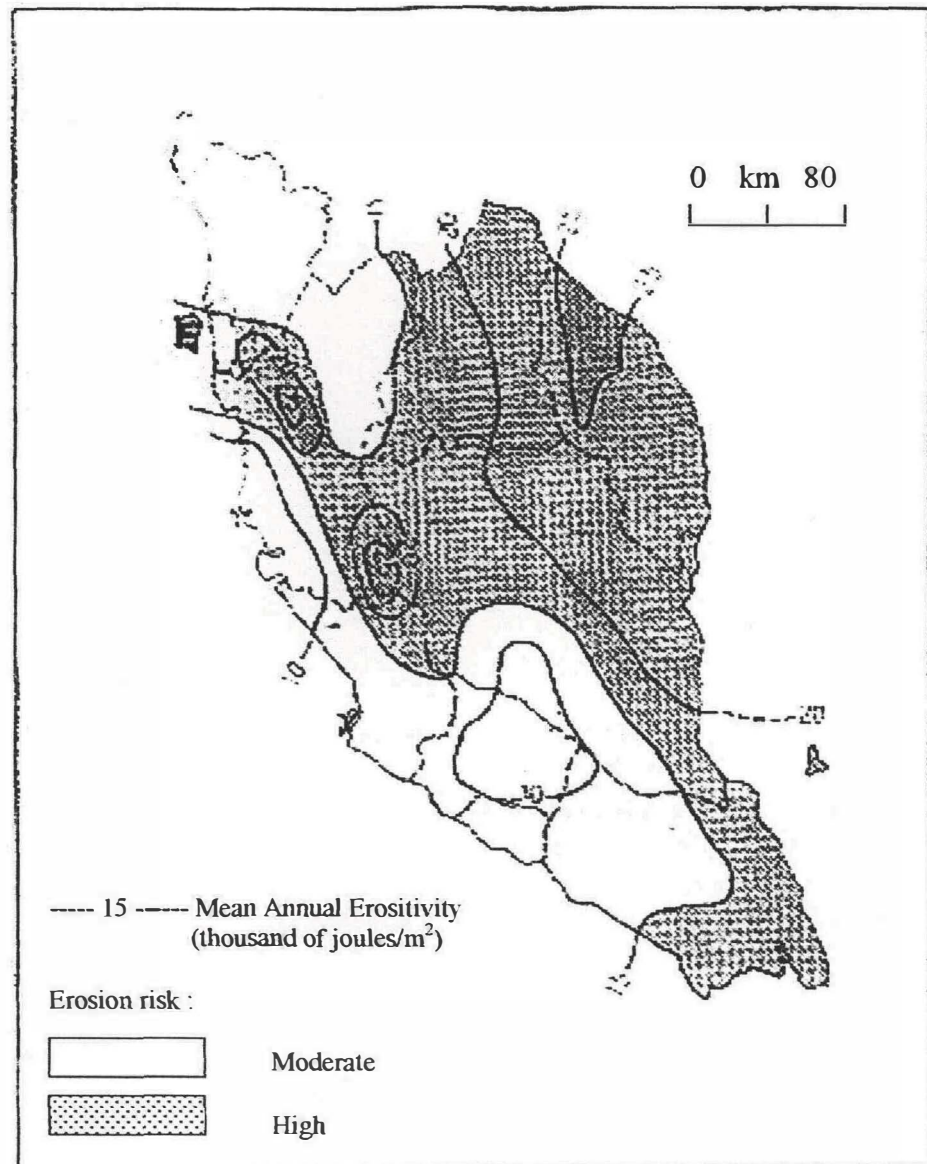


Figure 1.1 : Estimated Mean Annual Erosivity in Peninsular Malaysia after Morgan (1986)

Figure 1.1 indicates the mean annual erosivity (kinetic energy of rainfall) for the Peninsular Malaysia which was marked out by other researcher. The improved correlation proposed by this study, *that is, the relationship between the mean annual erosivity and the erosion for different slope gradient for local soil condition.*

The objective of this study was to obtain the empirical relationship between the total soil loss, *the slope gradient and slope length of the type of soil. Other factors* factors affecting soil loss such intensity and duration are kept constant to evaluate the main factors contributing to erosion which is the steepness of the slope.

Total soil loss equation proposed by other researchers will be also applied to Malaysia and the results will be evaluated.

Various method are employed in an attempt to analyse the data obtained. The Microsoft Excel spreadsheet and 'curve fitting' feature shall be utilised for the regression analysis to obtain the best fit line for the different equation used.

In the present study a soil loss from various slopes shall be recorded using a physical model study. *the experiment results will be compared with the experimental data* collected

## **CHAPTER 2**

### **LITERATURE REVIEW**

#### **2.0 General**

Erosion is a process whereby water or other natural forces tend to change, transport and displace soil and rocks from one place to another. The primary source of erosion is from logging, mining, construction and agriculture activities. When land is disturbed by these activities soil erosion tend to increase sometimes up to 100 times higher than its natural rate.

The impact of erosion and sedimentation have both in the economical and environmental aspects. Economical impact tend to be more visible such as losses of prime top soil for agriculture, the siltation of large monsoon drains and rivers and landslides that may cause loss of properties and lives.

Environmental impact includes excessive sedimentation in stream banks and bottom that cause losses of flora and fauna and polluting the streams,

Soil Erosion is a major problem of land management especially in tropical areas. adversely affects the agro-based industries and produces large amount of sediment.

Various researchers have argued the needs for more comprehensive data on soil erosion to predict this phenomenon (Lal, 1987).

## **2.1 Types of Erosion**

D'Souza (1973) lists that the main factors influencing the erosion process as :

- detaching capacity of the erosive agent
- the detachability of the soil
- the transporting capacity of the erosive agent
- the transportability of the soil

The detaching capacity of the agent and soil determined the material detach ability and make available for transportation by the transporting agent. Erosion may be either detachment or the 'transport limited'. If detachment exceeds the transporting capacity of the runoff then the amount of material moved is decided by the transporting capacity thus transport limited. The type of erosion that will occur will happen when the transporting exceed the detachment capacity.

Erosion by water is affected by two main agents which is raindrops that impacts the soil with enough force to loosen/detached the soil from the transporting agent. The second agent is runoff which may also detached the soil particle by scouring.

The kinetic energy or momentum of falling raindrops is the main agent of detachment through runoff may detach soil when its sediment load is markedly below its transporting capacity.

The main component of erosion is shown in Figure 2.1:

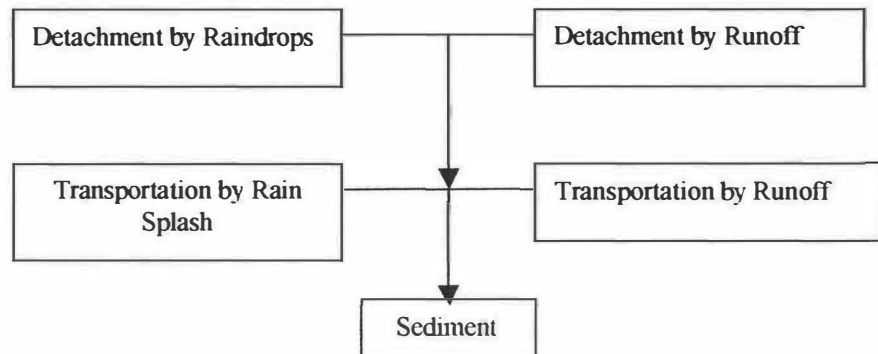


Figure 2.1 : Component of Erosion

### 2.1.1 Splash Erosion

Splash erosion is typically described as when vegetative cover is stripped away, surface is directly exposed to rainfall impact. On some soils, every heavy rainfall may splash as much as 100 tons/acre of soil. Some splash particle may rise up to 600 mm high above the ground. If the soil is on a slope, downhill. When the raindrops strike bare soil, the soil aggregate are broken up and fine particles and organic matter are separated from heavier soil particle,

soil. Factors affecting this sort of erosion are mainly the size of the droplets and the soil cover (Goldman et. al, 1986).

### **2.1.2 Sheet Erosion**

Sheet erosion is caused by shallow “sheets” of water flowing over the soil surface. These very shallow moving sheets of water are seldom the detaching agent, but the flow transport soil particles that have been detached by raindrops impact. The shallow surface flow rarely moves as a uniform sheet for more than a few feet before concentrating in the surface irregularities.

Sheet erosion is the uniform removal of soil in thin layers by the forces of raindrops and overland flow. It can be very effective erosive process because it can cover large areas of sloping land and go unnoticed for quite some time.

Sheet erosion can be recognised by either soil deposition at the bottom of a slope, or by the presence of light – coloured subsoil appearing on the surface. If left unattended, sheet erosion will gradually remove the nutrients and organic matter which are important to agriculture and eventually lead to unproductive soil. Figure 2.2 shows a case of sheet erosion along a fence.





Figure 2.2 : Sedimentation of Soil along fence line seen as indication of sheet erosion  
(source : <http://www.fao.org/docrep/T1765E/t1765e0c.htm>)

### 2.1.3 Rill Erosion

Rill erosion begins when shallow surface starts to change to deeper flow and the velocity and turbulence of the flow increase. The action begins to cut tiny channels called “rills” that are a few inches deep.